TIMBER VS. COMPOSITE/PLASTIC PILE FENDER SYSTEMS IN PEARL HARBOR MAINTENANCE COST COMPARISON

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Abstract

The Navy has traditionally used treated timber materials for fender systems for piers and wharves in Pearl Harbor. In recent years, the costs associated with the use of timber have escalated and the Navy has begun to use plastic piles at installations around the world to replace timber fender systems. Plastic fender systems are more expensive, but have greater energy absorption capabilities and are more resilient to environmental decay. To determine whether plastic piles are a cost saving alternative to treated timber, the present study compiled and evaluated existing technical data, maintenance/construction records and inspection reports from various Navy staff civil engineer offices and at the Navy Public Works Center Pearl Harbor (PWC). Since records at these various locations were not designed to present associated cost/maintenance data in a format suitable for an economic analysis, field surveys of over 3 miles of waterfront in Pearl Harbor and interviews with staff civil engineers and wharf building branch managers at PWC were conducted to supplement existing historical data. Through the gathered data, the maintenance costs of timber pile fenders are estimated and compared to those of composite plastic piles using manufacturers' quotes and from reports compiled by the Navy Civil Engineering Laboratory (NCEL). For the expected life cycles of timber piles observed in Pearl Harbor this analysis shows the proposed plastic system to be more cost effective for shore facilities with remaining service lives of greater than ten years.

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1. Background

During a 26 July 1996 meeting with CDR Lynn & LCDR Weisenburger of Commander in Chief Pacific Fleet (CINCPACFLT) Facilities Department interest was expressed in determining whether the use of the latest composite/plastic piling systems was of a cost saving alternative to the Navy in comparison to the traditional timber pilings for fender systems in Pearl Harbor. There is a debate whether it is more cost effective to use composite/plastic piles in the construction of fender systems in Pearl Harbor as opposed to the timber piles over a specific time period. The composite/plastic piles are more expensive and, therefore, incur a much greater capital cost over timber piles. The plastic/composite piles, however, are supposedly much more durable than their timber counterparts, which could save on recurring maintenance costs.

Further interest in this subject was expressed during meetings with both CDR Claussen, Commander Naval Base (COMNAVBASE) Pearl Harbor Staff Civil Engineer, and CDR Bengtson, Navy Public Works Center (PWC) Pearl Harbor Production Officer, on 28 August 1996. It seems that the use of treated timber piles is becoming more and more difficult due to environmental and Occupational Safety and Health Administration (OSHA) requirements. Also, plastic piles have recycling capabilities in Hawaii. Preliminary study for a specific facility has indicated that the use of plastic piles will be more cost effective than timber piles (Matsuda, 1996). Both CDR Claussen and CDR Bengtson suggested a more comprehensive study is needed to determine the most cost saving alternative.

There is information on construction and maintenance costs of fender systems for piers and wharves in the Pearl Harbor area, but this information is not compiled or organized in any usable form. The information can be found at various separate staff civil

engineer offices and commands in the Pearl Harbor area. To date, no attempt has been made to compile and analyze this information. The objective of the present study is to compile and analyze existing data on timber usage, material costs, construction costs, failure characteristics and disposal costs in determining the costs vs. benefits of switching to composite/plastic piles. The analysis performed in this study would be of tremendous use to the Navy in determining the most efficient use of maintenance/construction dollars for pile supported fender systems for piers and wharves in Pearl Harbor.

2. Introduction

2.1 General Background

A fender system is a structural system which stands between a berthed ship and the pier or wharf (shore facility). The fender system is designed to absorb or dissipate the impact energy during the berthing of a ship without causing permanent damage to the ship or the shore facility. Once the ship is successfully berthed and moored to the shore facility, the fender system continues to provide the interface between ship and shore and transmits the environmental loads (wind, waves and current) on the ship to the structure. For submarine and other low-profile ship berthing, the fender system also provides a physical barrier to prevent the vessel from going underneath the pier and causing a major accident.

The fender design chosen to protect a particular pier or wharf is highly dependent on the berthing practice employed at the particular naval facility. Typically, large ships are expected to be brought into berth assisted by two or more tug boats. Smaller ships in some locations may be allowed to come in on their own power. When assisted by tugs, the ship would arrive off the berth and parallel to it. The ship then fully stops in the water and the tugs push and pull the ship transversely toward the berth to make as much contact with the fender system as possible. When unassisted by tugs, the smaller ship will be eased into its berth at some slight angle, referred to as the angle of approach. In this case, the initial contact is limited to a relatively small portion of the fender system.

Most Navy ships are berthed against separators placed between the vessel and the fender system. This practice is the most significant difference between commercial ship berthing and naval ship berthing. For aircraft carrier and submarine berthing,

separators are mandatory. For surface combatant ships, even though separators are not needed, they are preferred to direct the berthing forces at the waterline (where the ship is strongest). Berthing against separators, which are usually floating camels, concentrates the impact energy to a small length of the fender system as well as applies the energy at some distance below the deck. This aspect is recognized in all fender system designs for Navy ships. Fender systems designed for commercial ships do not usually meet the standard required for the berthing of Navy ships (MIL-HDBK-1025/1, 1994).

2.2 General Designs

According to the military handbook, “Piers and Wharfs” (MIL-HDBK-1025/1, 1994) the Navy uses timber fender systems for both surface and submarine vessels berthing along concrete shore facilities. The specific fender design is driven by the unique requirements of each class of vessel and the structural requirements of the shore facility, but the general design is based on two typical configurations on piers and wharves constructed of concrete. The first configuration is based on the use of driven piles (see Figure 1) and the second uses a “hanging” configuration (see Figure 1). These two configurations cater to different types of vessels which apply berthing loads at different elevations, i.e. submarines apply loads well below the free surface as opposed to surface vessels applying loads at the free surface.

The driven pile configuration employs timber pile systems to absorb the loads induced by vessels. The piles are usually driven to a specific depth to provide sufficient resistance to the design loads. The piles are attached to the bull rail and columns (see Figure 1) of the shore facility by a supporting structure made up of timber members such as walers, chocks and blocks. These supporting members are designed to maintain the pile position during loading and are designed for a specific pile layout and

shore facility configuration. The members are usually connected together by boring and bolting. The walers are designed to: spread the load induced on a single pile over a greater length of the bull rail, act as a mounting area for chocks, and provide a convenient mounting arrangement to the pier or wharf. The chocks act as separators between adjacent piles. The blocks are used as separators between the waler and the bull rail. The timber fender system is tied to the bull rail by 'T' bolts which are inserted and turned to produce a mechanical attachment through the waler into the concrete bull rail.

2.3 Timber Fender Systems in Pearl Harbor.

The general timber fender designs outlined above were reconfigured to meet the specific berthing requirements and shore facility designs in Pearl Harbor. The Pearl Harbor shore facility locations which employ timber fender systems include Naval Station (NAVSTA), Submarine Base (SUBASE), Fleet Industrial Supply Center (FISC) and the Naval Shipyard (NSYD). In order to classify these specific configurations site visit surveys of existing timber fender systems covering over 3 miles of waterfront were conducted on 22, 23 and 27 September 1996. Each facility was inspected and the specific fender arrangement was documented (see Appendix A).

Some typical Pearl Harbor timber fender systems are shown in Figures 3 and 4. From this survey, it was evident that there are basically three configurations of timber fender systems presently employed in Pearl Harbor. These configurations are specified in Table 1. The first timber fender configuration is a driven pile system. This configuration slightly varies at different locations in Pearl Harbor basically by the placement and/or number of piles, walers, chocks and blocks as discussed in the military handbook (MIL-HBK-1025/1, 1994). The second configuration is a "hanging pile" design which ties the timber pile system to two points on the shore facility, one at the bull rail and the other

on a column section and was only observed at the "Mike" docks (M 1-4) on Naval Station Pearl Harbor (NAVSTA). The third configuration is basically one of the two aforementioned timber systems employed as a secondary system to a primary fender system. This arrangement can be found in areas of the shore facility at which a permanent berthing location has been assigned. These primary systems, which are designed for larger vessels, usually employ other types of fender systems, such as pneumatic floating systems with either concrete pile or steel sheet pile backing in some areas. The timber are used to berth smaller vessels and prevent equipment and debris from moving under the pier or wharf where they can cause damage to the shore facility.

Some of the existing timber fender systems at these commands are being demolished and replaced by Military Construction Projects (MILCON) or retrofitted using other types of fender systems. From the site visit surveys conducted on 22, 23 and 27 September 1996, an existing timber fender material quantity take off estimation was performed (Appendix A). The estimated quantities for each group of the shore facilities is summarized in Table 2. It was estimated that there are 4,715 piles along 19,480 linear feet of shoreline. There also are approximately 23,159 linear feet of 12"x12" timber walers, 18,667 linear feet of 8"x12" chocks and 4,146 linear feet of 4"x12" block. The most popular fender design seems to be the driven type with a single upper waler, chock, block layout. The pile distance on center seems to vary, but is usually around 5' on center. The initial goal of this survey was to survey all the facilities using timber fender systems in Pearl Harbor. The only areas in Pearl Harbor not surveyed were West Lock and areas operated by NSYD, due to restricted access.

Facility	Fender Type (timber)	Pile Size & Layout	Waler Size & Layout	Chock Size & Layout	Tie-in/Block Size & Layout
B 22 - 26	driven pile	14"-18" @ 4'-6' oc. w/ 9 pile clusters @ 60' oc.	12"x12" upper & or lower (varies)	8"x12" upper & or lower (varies)	tie-in @ 6' w/ 4"x12" block
M 1-2	hanging pile 7.5' length	14" @ 3.5' oc.	12"x12" upper & lower	8"x12" upper & lower	tie-in @ 6' w/ 4"x12" block
M 3-4	hanging pile 7.5' length & combination	14" @ 3.5' oc.	12"x12" upper & lower	8"x12" upper & lower	tie-in @ 6' w/ 4"x12" block
S 1A-1B	driven pile & combination	14" @ 4.5' oc.	12"x12" upper & lower	8"x12" upper & lower	tie-in @ 5' w/ 4"x12" block
S 4-5	driven pile & combination	14" @ 3' oc.	12"x12" upper	8"x12" upper	tie-in @ 8.5' w/ 4"x12" block
S 8-9	driven pile	14" @ 2'-6' oc.	12"x12" upper	8"x12" upper	tie-in @ 9' w/ 4"x12" block
S 10-14	driven pile	14" @ 2'-7.75' oc.	12"x12" upper & or lower (varies)	8"x12" upper & or lower (varies)	tie-in @ 5' w/ 4"x12" block
S 15-21	driven pile	14" @ 2'-5' oc.	12"x12" upper & or lower (varies)	8"x12" upper & or lower (varies)	tie-in @ 5' or 9' w/ 4"x12" block
K 3-10	driven pile	14" @ 5' oc.	12"x12" upper	8"x12" upper	tie-in @ 5' w/ 4"x12" block
F 1	driven pile	14" @ 5.5' oc. w/ 9 pile clusters @ 50' oc.	12"x12" upper	8"x12" upper	tie-in @ 6.5' w/ 4"x12" block
F 9-10	driven pile	14" @ 5' oc.	12"x12" upper	8"x12" upper	tie-in @ 6' w/ 4"x12" block
F 12-13	driven pile	14" @ 5' oc.	12"x12" upper	8"x12" upper	tie-in @ 5' w/ 4"x12" block

Table 1 - Surveyed Timber Fender System Layouts - Pearl Harbor

Facility	Fender Type: timber pile	Waterfront Using Timber Fenders (lf)	14"-18" Timber Piles	12"x12" Timber (lf)	8"x12" Timber (lf)	4"x12" Timber (lf)
B 22 - 26	driven	2762	876	2454	2221	293
M 1-4	hanging & combination	1374	393	2748	2290	137
S 1A-1B	driven & combination	1100	206	2200	1941	220
S 4-5	driven & combination	668	221	618	417	76
S 8-9	driven	763	204	683	532	90
S 10-14	driven	1277	400	1060	982	720
S 15-21	driven	4118	836	5046	3695	994
K 3-10	driven	4251	863	4886	3894	977
F 1, 9, 10, 12-13	driven	3167	716	3464	2695	639
Surveyed Totals		**19,480**	**4,715**	**23,159**	**18,667**	**4,146**

Table 2 - Estimated Existing Timber Fender Material Quantities - Pearl Harbor

3. Timber Pile Life Cycle Estimation

3.1 Timber Failure Modes.

Timber fenders in Pearl Harbor are subject to deterioration from decay or rot, attack by marine borers and insects, splitting and checking brought about by drying shrinkage or by the alternate wetting and drying cycle within the splash zone, corrosion of connections, abrasion, and overloading. The following modes of failure have been observed in Pearl Harbor.

3.1.1 Marine borer and insect attack. Marine borer attack is a very serious problem for timber structures in the splash and submerged zones. The destructive effects of two large groups of marine invertebrates, the Teredo, commonly called shipworms, and the Limnoria, commonly called woodgribbles have been documented (CHESDIV 55-94(147), 1994). Shipworms (Teredo) are mollusks and are distantly related to the oyster and the clam. Shipworm species are found in nearly all saltwater harbors and oceans of the world, except for the colder waters of the Arctic and Antarctic regions.

Infant shipworms float with the tides and either attach themselves to fixed objects or die. Should they settle on submerged timber during the first 48 hours of their life, they begin to change in physical appearance, with the body elongating, while tow clam like shells begin to auger into the wood. As the shipworm begins to burrow and grow, it becomes more worm like in appearance. In time the shipworm orients its body parallel to the grains of the timber member. Eventually, the interior of the pile will become completely riddled with burrows, although externally no evidence of attack is apparent. The original hole in the surface of the timber created by the infant shipworm is no larger than the diameter of a pinhead.

Woodgribbles are crustaceans related distantly to the crab and shrimp family. They are quite small, averaging only 1/8 to 1/4 inch in length. This tiny organism is a voracious wood chewer, with its appendages and mouth developed for rasping and biting. Infant woodgribbles are released onto or inside the submerged timber member at birth. Ordinarily woodgribbles do not burrow deep inside the timber surface but limit their attack to shallow surface trenches. In timber piling, this results in a slow but continual reduction in pile diameter. Damage is most frequently found at the water or mud lines, where the woodgribble population is the greatest. Severe attack can reduce the outside diameter of an untreated pine or Douglas fir by up to 6 inches in 1 year (NAVFAC P-990).

Termites are the most destructive type of insect life to attack above water. They feed on cellulose matter contained in timber. Timbers most subject to attack are wales, chocks and blocks.

3.1.2 Shrinkage Damage. Drying causes timber to shrink. After installation this drying process continues, especially in hot dry climates, and the timber members split and check. This shrinkage also causes bolts to loosen in connections which, in turn, causes slippage and deflections in timber members and even distortion and weakening of the entire assembly.

Splitting and checking create an opening in the timber face or end that is an ideal means of access for insects and borers. These openings also tend to accumulate moisture and dirt, which can also easily lead to decay.

3.1.3 Fastener Corrosion. Due to the extremely corrosive effects of saltwater, the steel connections used in timber fender construction are susceptible to deterioration. This effect can be retarded by using galvanized steel bolts, washers and nuts.

3.1.4 Abrasion Damage. Abrasion damage is usually caused at the interface of camels and timber piles while a vessel is at berth. The camel rubs against the seaward side of the piles, in response to constant pitching and yawing motion of the vessel induced by wave action. This rubbing wears away of the outer fibers of the timber pile, thus exposing the less well treated inner fibers of the wood. This exposure is usually exploited by woodgribbles, which accelerate the rate of deterioration of the pile. This deterioration cycle is extremely destructive because the piles are being weakened at an area where concentrated horizontal loads are transferred to the fender by the camel (MIL-HDBK-1025/1, 1994).

3.1.5 Overloading. Bending failure of piles due to overloading may occur when the vessel is at berth or during berthing operations. Wind pressure on a vessel is transferred to the fender system. While the vessel is berthed by keeping the vessel at berth beyond the design wind speed may result in excessive loading on the fender piles. During berthing operations, accidental impact of a vessel on the fender system is another cause of pile structural failure. This type of loading is particularly damaging due to the large energies with the moving mass of the vessel. This was observed at various locations in Pearl harbor where relatively new piles had been broken by vessels coming into berth at speeds too great for the design fender energy absorption capacity.

3.2 Maintenance Record Review

During investigations and interviews at various commands it became evident that no maintenance records were being kept which could be used to conduct a maintenance cost analysis of timber fender systems. This finding was echoed by a past study conducted by the Naval Audit Service (Audit Report, 1985). These offices had financial records which gave information on repair project costs, but these records could not be used to determine life cycles of timber fender systems for the following reasons:

1. Damaged piles and locations are identified in the records along with quantities of support members (walers, chock, block) but, during repair work, PWC may have to replace more material than originally planned. This is due to further fender damage occurring between the time of initial estimation and the start time of repair work. This time period could be 1 month or longer. According to these records it is not clear exactly which piles/components were actually replaced and when.

2. The records that are being kept are more or less used for accounting purposes and do not specify cost, materials and life cycle data in a format conducive to a maintenance analysis. Also, costs of projects are recorded under Job Order Numbers, in which costs for several projects are sometimes recorded using the same Job Order Number.

3.3 Inspection Record Review.

Inspection records were also studied to determine whether any timber fender documentation was made. However, these inspections did not usually cover the fender systems of the shore facilities, their focus was on the structural members of the piers and wharves, which were usually concrete or steel. But, an inspection report conducted in 1994 at SUBASE (CHESDIV, 1994) documented deterioration of timber fender pilings. This report showed the influence of marine borer attack on the piles. But, no estimation was made concerning the rate of deterioration. Thus, the life cycle of timber piles could not be determined from any existing inspection records.

3.4 Engineering Study Review.

A review of some of the engineering studies on file at various Naval Commands at Pearl Harbor were of value in confirming the information gathered during interviews with

regard to failure modes and estimated life cycle of timber fender piles. The most prevalent failure modes documented were overloading and biological deterioration (Ferver Engineering, 1980; and Audit Report, 1985)

At warm water Naval installations, biological deterioration of timber fender systems is a serious problem. The commonly used treatment of 20 lbs of creosote per timber pile has not proven effective against Limnoria attack and dual treatment apparently causes an embrittlement of the timber (Ferver Engineering, 1980). It was reported that a life expectancy as brief as 2-3 years can be expected (Ferver Engineering, 1980). Others reported that biological deterioration is not a problem because ship caused breakage occurs first[1,4] (see List of Interviews). This may be only partly correct. Because of the ability of Limnoria to gain entrance to the interior of the piling through cracks and small holes in the wood, detection is difficult or impossible until surface destruction is visible. According to the Ferver Engineering report, during an incident at the San Diego Naval Station, several apparently sound single treated fender piling which had been in place 3.5 years were broken. Close inspection revealed substantial Limnoria infestation and damage to the interior of the piling. While the incident involved ship berthing impact, the impaired strength of the piling was a contributing cause without which breakage might not have occurred.

A study conducted by the PWC Pearl suggested a life cycle of 5 years for timber fender piles (Matsuda, 1996). A report from the Naval Engineering Service Center (NFESC) quoted engineers from the Port of Los Angeles estimating the usable life of a timber pile to be 3-8 years (Hoy, 1995). The study conducted by the Naval Audit Service used a conservative estimate of 8 years for the expected life of a timber pile in Pearl Harbor (Audit Report, 1985). All of the aforementioned studies reported that the major disadvantage of this timber system is the biological deterioration of the timber piling in the sea water environment.

3.5 Life Cycle Estimation.

Since quantitative inspection/maintenance data on timber fender systems was not found for timber systems in Pearl Harbor, other sources of information concerning failure modes and life cycles of timber fender systems were sought. The aforementioned engineering studies were augmented by a series of interviews with marine construction and facilities maintenance personnel to gather data through observation and experience with timber fender systems in Pearl Harbor. It was determined from the information provided by these interviews that the range of usable life of a timber pile in Pearl Harbor is between 3 and 5 years[1,6,7]. This range was specified for failures precipitated by environmental deterioration of the timber pile. The major disadvantage of this timber system is the biological deterioration of the timber piling in the sea water environment.

One other approach was considered in the life cycle analysis. This approach was to estimate the average number of piles that are being replaced per year. Therefore, by estimating the number of piles presently in use as fender systems, it would be possible to derive the average life cycle of a timber pile. This approach did not produce tangible results. It is estimated that 350 piles per year are being replaced in the Pearl Harbor area. The following variables make it impossible to derive a life cycle. These piles are only being replaced in critical berthing areas. The lack of available money due to budget constraints, limits the fenders which are replaced. Thus, more piles are deteriorating per year than are being replaced. Also, the piles that are being replaced include piles, which may be relatively new but are damaged due to berthing loads beyond the design load of the fender system. This approach could be used very effectively if the historical records are kept concerning the replacement of piles for these critical berthing areas.

Information provided concerning operational (loading) failure suggested that no range or average life span could be determined. It was stated that operational failures were of a random nature[1,4,6]. Operational failures of timber fender systems cannot be predicted from existing data because no records exist. Damage due to vessels is random in nature and depends on such factors as: fender system design, type of vessel berthed, frequency of use of a particular fender system, vessel/tug pilot experience, facility location (predominant leeward or windward loading), and seasonal weather conditions. It was concluded that no estimation can be made regarding operational failure of timber piles[1,4,5,6].

Since operational failure was determined to be random and that environmental decay is the primary weakness of timber systems, It was concluded that the life span of timber fender systems is 3 - 5 years in Pearl Harbor waters.

4. Plastic/Composite Fender Systems

4.1 Proposed Plastic/Composite Fender Systems.

According to reports from the Naval Facilities Engineering Service Center (NFESC) the Navy is researching several composite/plastic type fender pile configurations. These configurations include structural pipe cores, concrete filled fiberglass shells, fiberglass and steel reinforced plastic piles and combinations thereof (Warren, 1996).

PWC Pearl is in the process of testing the use of composite/plastic piles and support materials on future fender and camel construction/replacement projects. The brand of material being considered for this experiment is the system developed by Seaward International Inc. Seaward International has developed the Seapile and Seatimber series for use as a replacement system for timber fender design and construction. This product is designed to be comparable in structural specifications to timber and is installed using the same method and equipment as timber piles. This system is attractive to PWC Pearl wharf builders because of its similarity to timber construction, longer estimated service life and recycling capabilities. The Seaward pile system is constructed using virtually the same hardware, tools equipment and methods as timber fender systems[2,3,6,8]. Table 3 shows the structural specifications for both timber and plastic piles.

Pile Type	Max. Allowable Bending Stress	Berthing Load, P (kips)	Deflection Load (in.)	Energy (in-kips)
Plastic (13" dia.)	2.4	6.59	10.52	35.01
Timber (14" dia)	3.77	10.62	4.92	26.15

Table 3. Structural Specifications - Plastic vs. Timber

4.2 Estimated Life Cycle.

The Seapile environmental life expectancy was estimated to be 25 - 50 years[8]. Timber piles wrapped with plastic have been used for a long time. Some of these wrapped piles have lasted for 25 years (Hoy, 1985). For the life cycle maintenance cost analysis herein, an estimated life expectancy for plastic piles will be assumed to lie between 10 and 25 years. These figures are conservative because of the lack of historic data concerning plastic piles (Hoy, 1996). These figures are also conservative operational life expectancies due to the fact that the 13" diameter Seapile has an energy absorption capacity of 35.01 in.-kips as compared to 26.15 in.-kips for a 14" diameter timber pile (Hoy, 1995).

5. Capital/Maintenance Cost Analysis

5.1 Material and Construction Costs.

The material costs shown in Table 4 were quoted from PWC Pearl Harbor[3] and Seaward International[8]. The total plastic fender material cost was $4,985 compared to $1,511 for timber. The plastic material costs are over three times that of timber.

Fender Material	cost each, timber	cost/l (lf), timber	cost each - Plastic (Seapile)	cost/l (lf), Plastic (Seapile)
pile, 65'	$886.28	$13.64	$2,925.00	$45.00
waler,12"x12"x20'	$267.87	$13.39	$900.00	$45.00
chock,8"x12"x20'	$208.92	$10.45	$800.00	$40.00
block, 4"x12"x20'	$147.96	$7.40	$360.00	$18.00
sub total	**$1,511.03**		**$4,985.00**	

Table 4 - Quoted Fender Material Costs

Fender construction (replacement) costs were estimated using information provided by PWC Pearl. The estimation was performed using the typical replacement project of demolishing and replacing 10 piles. The construction operation was broken down into the following 9 activities and associated costs of labor, equipment and disposal were applied. The various rates applied are the 1996 rates applied by PWC Pearl for specific work. These activities and costs are listed in Table 5 for both timber and the Seapile fender replacement estimation. These calculations can be seen in Appendix B.

Activity #	Description	Timber Costs	Plastic Costs
1	Draw, Load, Transport Materials	$677	$677
2	Stage Materials	$472	$472
3	Mobilization	$885	$885
4	Demolition	$2,494	$2,494
5	Construction	$2,494	$2,494
6	Load, Transport Debris	$676	$676
7	Prep. Debris for Landfill	$882	$882
8	Load, Transport Debris to Landfill	$676	$676
9	Dump Costs	$928	$710
Totals	Total Material Costs	$10,668	$33,908
	Total Construction Costs	$7,698	$7,698
	Total Disposal Costs	$2,486	$2,268
	Total Costs For 10 Pile Job	$20,852	43,873
	Total Cost Per Pile	$2,085	$4,387

Table 5 - Pile Replacement Activity Costs and Totals for a 10 Pile Job

The mobilization, demolition, construction and disposal costs are assumed to be the same for both timber and the plastic system. This was assumed because the Seaward system employs basically the same construction method, tools, connections and equipment as timber[6,8].

5.2 Economic Analysis Methodology.

The analysis is based on the scenario that a fender would be replaced today and periodically thereafter at the end of the pile life cycle for the remaining design life of the shore facility. The initial replacement costs are included in the analysis to provide a total cost comparison so that planners or engineers can identify the most cost effective repair option, based on the remaining design life of the facility. The analysis was conducted under the following assumptions and observations.

1. A typical fender system consists of: 1 - 13"x65' pile at 5' on center; 1 - 12"x12"x5' waler, 1-8"x12"x3.9' and 1-12"x12"x1' block/tie-in at 5' on center.

2. A typical repair job would replace 10 damaged fender piles and associated supporting members, including the wales, chocks, blocks and hardware. The limited material staging area, the facility outage duration, and the restricted equipment working area, due to the presence of fixed pier/wharf side equipment make it extremely difficult to undertake larger scale repair projects. The 10 pile job size represents a typical repair project size in Pearl Harbor by which PWC usually can set up and execute fender demolition and repair due to the constraints listed above[6]. Repair projects of less than 10 piles are usually grouped with other repair projects in the vicinity to minimize mobilization costs[6]. Larger projects are basically a series of these 10 pile jobs because equipment

has to be moved to the next location and the site area constraints along the waterfront preclude the staging of large amounts of materials[6].

3. Costs such as drawing materials, transporting materials, staging materials, transporting debris, and hauling debris to the landfill are assumed to be the same for both timber an plastic fender projects[6].

4. The savings resulting from recycling the plastic piles include the debris transportation and the landfill dumping costs. No other cost savings were assumed.

5. The life cycle is the period of time for which the fender system continues to provide the intended design energy absorption, since the energy absorption of the system is performed mainly by the piles (MILHBK 1025/1, 1994).

6. The expected life cycle of a timber pile is between 3 and 5 years. A 5 year expected life cycle, tends to be optimistic, because of the existence severely deteriorated piles which were installed 5 years prior, not loaded by vessels, and were subject only to environmental decay[7].

7. The expected usable life of a plastic Seapile between 10 and 25 years was chosen in order to provide a "low end" for comparison. This is a conservative estimation compared to the manufacturers claim of 25 to 50 years. An expected life of 25 years, which is still conservative according to the manufacturer, was used because of claims made by the Port of Los Angeles officials who observed life cycles of 25 years for timber piles wrapped in plastic, which protected the timber piles from environmental decay (Hoy, 1995).

8. All replacement costs except timber are increasing at the rate of inflation. The cost of timber is inflating at a rate of 14.87 per year due to the lack of large trees available for the production of large timber piles (Williams, 1994).

9. The cost of plastic materials will increase with the rate of inflation even though cost should decline in the future due to advances in manufacturing and the establishment of the recycling industry[8].

10. The average inflation rate for the next 50 years is 3.7 %. This figure was obtained by averaging the successive annual percent change in the Producer Price Index over the past 48 years (Census Bureau, 1975; Labor Dept., 1996; and Census Bureau, 1994). See Appendix C for calculations.

Two economic analyses were performed. The first analysis assumes the plastic fender debris will be disposed of in the landfill as for the timber debris. The second analysis assumes the plastic will be recycled and will not have to be disposed of in the landfill.

The analysis was conducted using the Excel spread sheets as shown in Appendix C. The cost of replacement for each fender type, plastic and timber were grouped together in the following manner. The cost of material (plastic or timber only) is denoted by (M). The other costs (labor, equipment, mobilization, disposal, etc.) are grouped together as one cost (C). The total of these costs, M + C, represent the cost of fender replacement today. The present worth of these future costs are then calculated using the following equation.

$$P = C + \frac{M(1+j)^n}{(1+i)^n}$$

Where i = average inflation rate and j = inflation rate of timber. For the calculation of P for plastic, i = j. These future costs are then accrued over each replacement life cycle

for each fender system which yields the total accumulated replacement (maintenance) cost per pile location.

5.3 Capital/Maintenance Cost Comparison.

Capital/Maintenance costs are plotted against projected remaining facility design life of 10, 20 , 30, 40 and 50 years in Figures 4 and 5. The first plot represents Case 1, which assumes that removed plastic material will be disposed of like that of timber (see Figure 4). The second plot, Case 2 (see Figure 5), assumes that the removed plastic will be recycled, so no disposal costs are incurred. The results show that for facilities with design lives of greater than 10, plastic is more economical. Ranges were used for expected pile life and projected design life values in order to provide flexibility in determining the "best choice" replacement fender system for a particular facility. This approach is similar to the design decision making process when considering design alternatives for a particular construction project.

Table 6 is a cost comparison matrix which summarizes the results of the aforementioned economic analysis. This table illustrates drastic differences in costs between timber and plastic systems, especially for longer remaining facility design lives.

In order to justify the use of plastic, it is reasonable to consider the point where the plastic system pays for itself in cost savings over timber. If it is assumed that the plastic pile system will last 25 years, the plastic system will pay for itself within 10 years if timber lasts 3 or 5 years. If it is assumed that the plastic system will last only 10 years and timber lasts 5 years, the plastic system will pay for itself in 20 years. This last scenario, assuming timber to last 5 years, does not seem to be realistic because of the observations of failures timber piles in Pearl Harbor[1,6,7]. Tables 7 and 8 show the cost savings of using plastic assuming a 25 year life cycle to that of timber assuming both 3 and 5 year life cycles.

remaining facility design life (yrs)	timber- 3 yr life ($)	timber- 5 yr life ($)	plastic- no recycle 10 yr life ($)	plastic- no recycle 25 yr life ($)	plastic- recycle 10 yr life ($)	plastic- recycle 25 yr life ($)
10	11,060	4,839	4,387	4,387	4,161	4,161
20	28,681	14,433	8,775	4,387	8,322	4,161
30	68,010	37,256	13,162	8,775	12,483	8,322
40	217,008	96,874	17,549	8,775	16,644	8,322
50	529,433	258,837	21,937	8,775	20,805	8,322

Table 6 - Timber vs. Plastic Fender Accumulated Replacement Cost Comparison

	accumulated cost savings per pile location (no recycling)			accumulated cost savings per pile location (recycling)	
design life (yrs)	present worth $	% savings		present worth $	% savings
10	6,673	60.3%		6,899	62.4%
20	24,293	84.7%		24,520	85.5%
30	59,235	87.1%		59,688	87.8%
40	208,233	96.0%		208,686	96.2%
50	520,659	98.3%		521,112	98.4%

Table 7 - Cost Comparison Results Plastic (25 yr. Life) vs. Timber (3 yr. Life)

	accumulated cost savings per pile location (no recycling)			accumulated cost savings per pile location (recycling)	
design life (yrs)	present worth $	% savings		present worth $	% savings
10	451	9.3%		678	14.0%
20	10,046	69.6%		10,273	71.2%
30	28,481	76.4%		28,934	77.7%
40	88,099	90.9%		88,552	91.4%
50	250,062	96.6%		250,515	96.8%

Table 8 - Cost Comparison Results Plastic (25 yr. Life) vs. Timber (5 yr. Life)

6. Conclusions

The life cycle of the fender pile is the most important factor in determining the most cost effective material type for design and construction. The life cycle of a fender pile system is determined by the structural integrity of the piles. It is important to identify when the pile fails to support its design energy absorption capacity. This means that if the pile is damaged, it will not support its intended load and will fail under operational loading. Since failures from operational loading are of a random nature and no data exists to statistically model operational fender loading characteristics in Pearl Harbor, failures caused by operational loading were not considered in the life cycle estimation of the fender pile system.

It has been observed that timber piles in Pearl Harbor become damaged from environmental factors such as shrinkage and marine borer attack at a fairly rapid rate. Since it has been shown that environmental deterioration can accelerate operational loading failure, deterioration due to environmental factors governs the estimation of pile life cycle. Through interviews and site inspections, the life cycle of a timber pile was estimated at about 3 years. At this point, it can be expected that the pile will become weakened from environmental deterioration and, therefore, become too weak to support its intended loading capacity. A reasonable estimate for the life cycle of a plastic pile can be reached from observations of timber piles wrapped with plastic lasting up to 25 years.

The analysis was made using the lower and upper bounds of the estimated piles life cycles, which are 3 and 5 years for timber and 10 and 25 years for plastic piles. Potential recycling capability exists in Hawaii and was also considered in the analysis, although no reduction in plastic material costs were assumed. The accumulated

present worth replacement cost for both timber and plastic for assumed remaining shore facility design lives were estimated for each of the projected usable life cycles of plastic and timber piles. It is observed that timber is more costly for each remaining design life. For each of the projected remaining design lives, the accumulated plastic fender replacement costs are less than those of timber. The plastic fender system, although incurs a much greater initial cost, will pay for itself through savings in maintenance, within 10 years if a 3 year life cycle is assumed for timber.

7. Recommendations

This study was conducted based on data obtained from personal interviews, engineering reports, and field inspection results. In order to substantiate the findings of this report, a study using actual historical data is required. Because no historical data exists in a usable form for an economic analysis it is imperative that a mechanism for recording the necessary information be put in place. The following recommendations are made to set up the necessary database to perform an economic analysis from historical records.

1. The Naval Facilities Engineering Command (NAVFAC) should design a database from existing "off the shelf" software, such as Microsoft Access. This database should be the standard throughout NAVFAC. This data base should include fender information such as: frequency of use, type of vessels berthed, method of berthing, orientation of berth (N, S, E or W etc.), type of fender system used, date installed, the contractor, how much did the work cost (material, hardware, labor, equipment), and projected remaining usable life of the shore facility. NAVFAC should delegate the responsibility for implementing this program to the Engineering Field Division (EFD).

2. The EFD should assist the Staff Civil Engineers (SCE) in their division with implementation of this program at the local level. The SCE's should be responsible for maintaining the data base at their command.

3. Navy Public Works Centers should keep track of job costs by breaking down these costs into line items to be given to the SCE's for input in their databases.

4. The Port Operations Department at cognizant Naval Stations should submit information on each berthing area such as frequency of use, vessel type, weather conditions, type of berthing (tug assisted etc.). This information should then be provided to the SCE office for entry into the data base.

The database designed using an off the shelf program can be easily passed and used between commands and be easily updated to keep up with the latest computer technology.

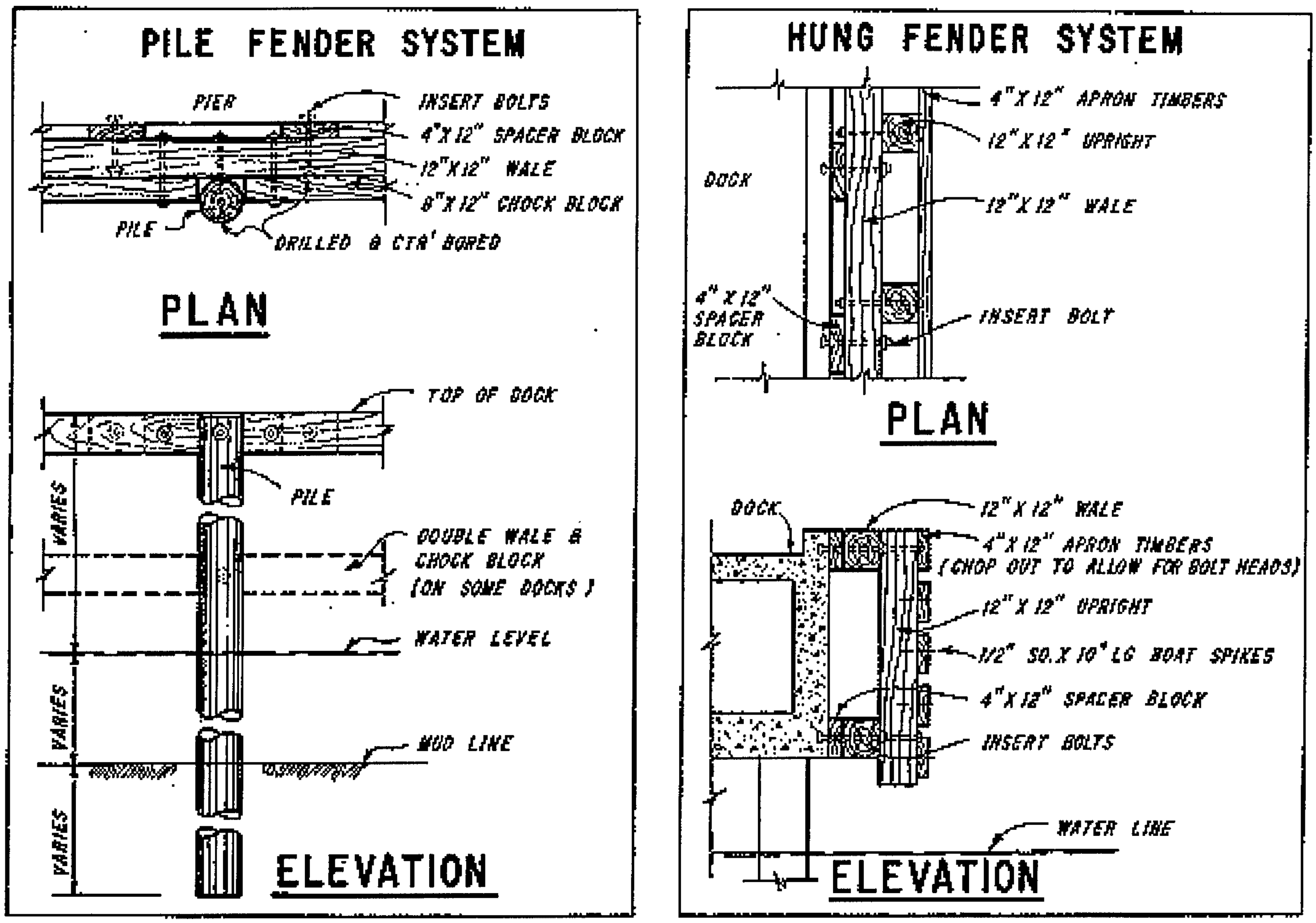

Figure 1. General Timber Fender System Designs

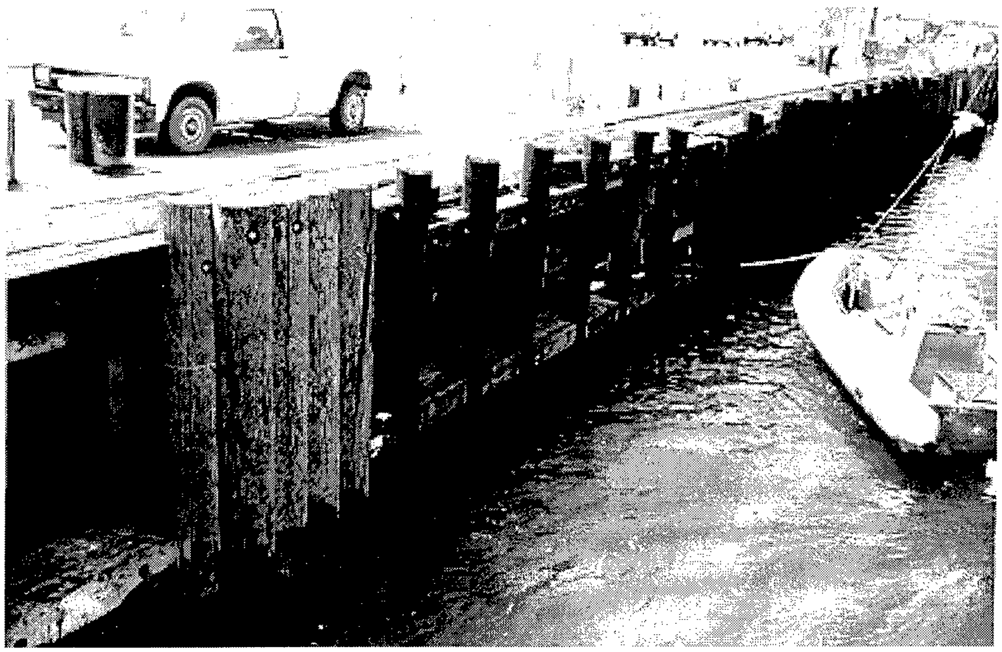

Figure 2. Typical Surface Vessel Timber Fender System - Pearl Harbor

Figure 3. Typical Submarine Timber Fender System - Pearl Harbor

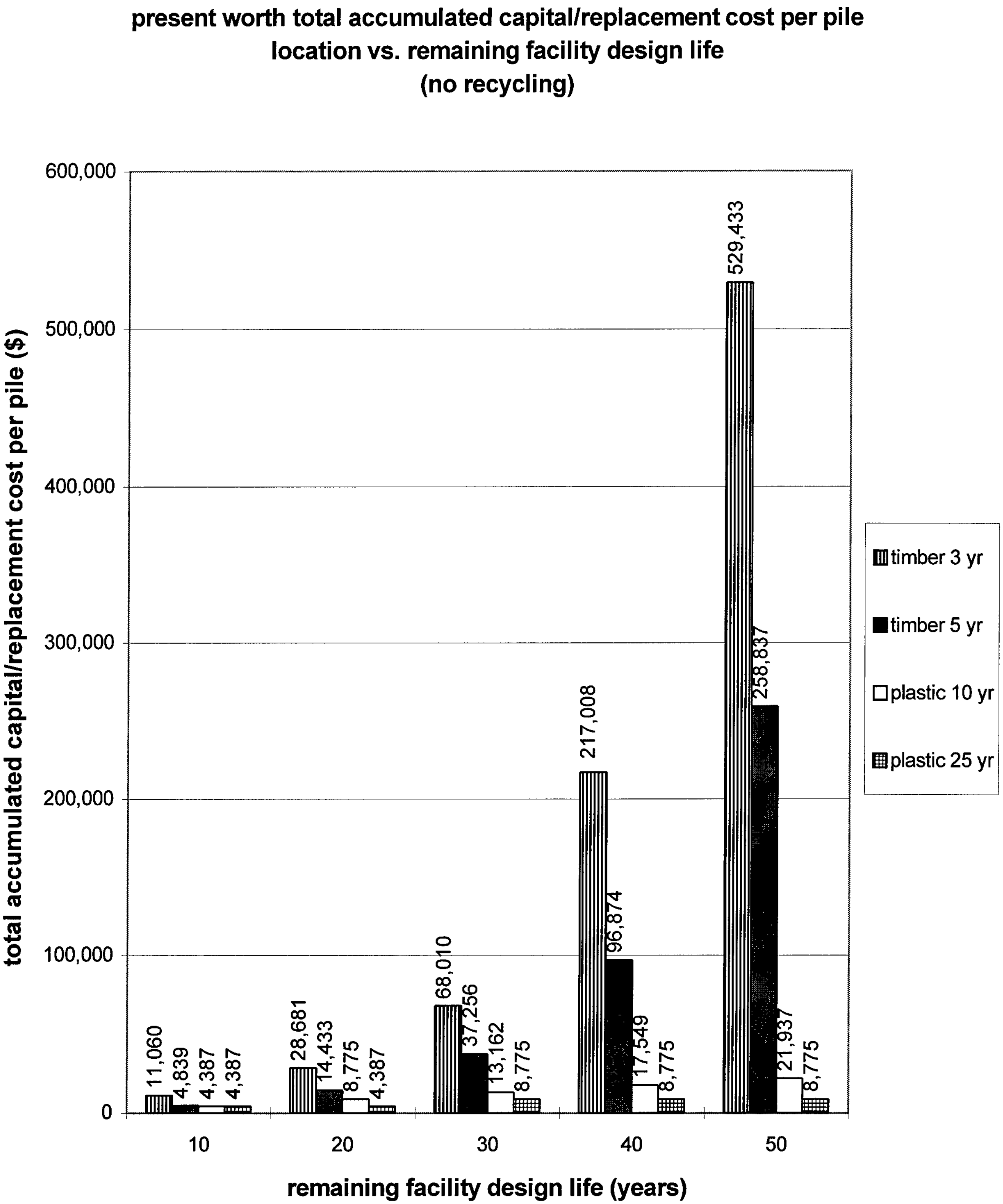

Figure 4. Total Costs (no Recycling) vs. Remaining Design Life

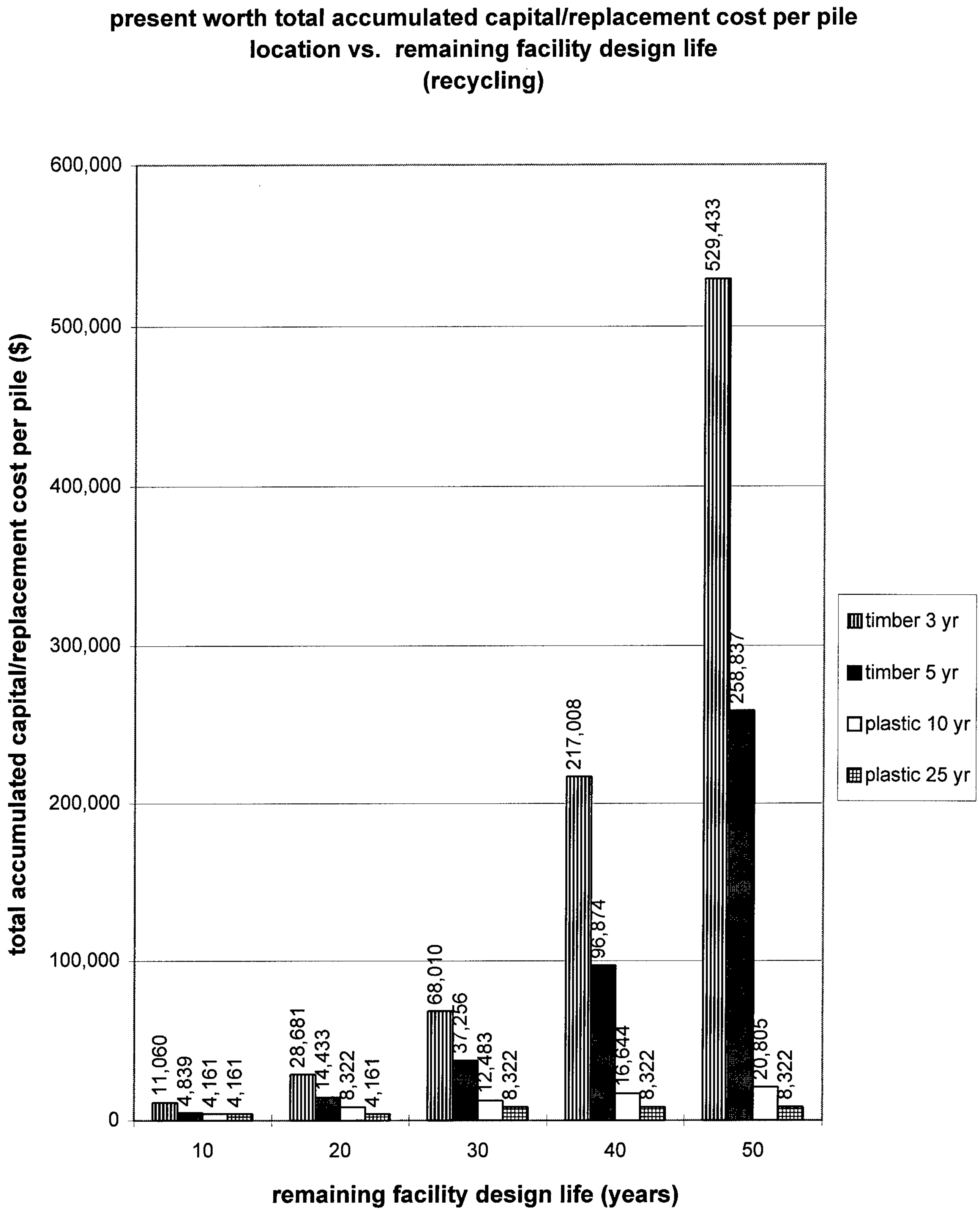

Figure 5. Total Costs (recycling) vs. Remaining Design Life

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4 Higgenbothem, QM1, Water Front Operations Coordinator, Naval Submarine Base, Pearl Harbor, personal interview and site visit 1 November 1996.

5 Kam, Donald, Facilities Manager, Staff Civil Engineering Office, Naval Station Pearl Harbor, personal interview 11 September 1996

6 Kekemu, Wayne, Branch Manager, Wharf Builders WC 521, Navy Public Works Center Pearl Harbor, personal interview 28 October 1996.

7 Kekemu, Wayne, Branch Manager, Wharf Builders WC 521, Navy Public Works Center Pearl Harbor, personal interview & site visit SUBASE S-9, 1 November 1996.

8 Taylor, Bob, Vice President, Seaward International Inc., Clearbrook, Va., telephone interview, 8 November 1996.

Appendix A

Field Survey Results and Existing Timber Fender Material Quantities

	inspection date		**9/21/96**							
Section	**1**	**beg STA=**	**2900**	**end STA =**	**1890**	NAVSTA		B-26 through B-22		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	18	6	1	1	1010	168	168		275	275
Fender Pile Cluster	18	60	7	7	915	107	107			
Chock	8x12	6	4.5	2	1010	1768	393	10.5		1768
Waler	12x12	6	6	2	1010	2020	337	12.0		2020
Block	4x12x12	10	1	1	1010	101	101	0.6		101
	inspection date		**9/21/96**							
Section	**2**	**beg STA=**	**1890**	**end STA =**	**1575**		NAVSTA		B-26 through B-22	
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	18	6	1	1	315	53	53		89	364
Fender Pile Cluster	18	60	7	7	315	37	37			
Chock	8x12	6	4.5	2	315	551	123	10.5		1890
Waler	12x12	6	6	2	315	630	105	12.0		2125
Block	4x12x12	10	1	1	315	32	32	0.6		133
	inspection date		**9/21/96**							
Section	**3**	**beg STA=**	**1575**	**end STA =**	**0**		NAVSTA		B-26 through B-22	
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	18	5	1	1	1575	315	315		499	863
Fender Pile Cluster	18	60	7	7	1575	184	184			
Chock	8x12	5	3.5	1	1575	1103	315	3.5		2205
Waler	12x12	5	5	1	1575	1575	315	5.0		2440
Block	4x12x12	10	1	1	1575	158	158	0.5		290

	inspection date		9/21/96							
Section	4	corner section				NAVSTA		B-26 through B-22		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	18	2	1	1	25	13	13		13	876
Chock	8x12	3.5	2	2	25	31	16	2.5		2221
Waler	12x12	3.5	3.5	2	25	50	14	4.0		2454
Block	4x12x12	10	1	1	25	3	3	0.2		293

	inspection date		9/21/96	
Section	summary	0- 2762 feet		
		amount of waterfront using timber fenders (lf) =		2925

Timber Material	size/dia.	totals
	(inches)	(num & lf)
Fender Pile	18	876
Chock	8x12	2221
Waler	12x12	2454
Block	4x12x12	293

	inspection date		9/21/96							
Section	1	beg sta =	0	end sta =	894	NAVSTA		M-1 through M-2		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3.5	1	1	894	255	255		255	255
Chock	8x12	3.5	2.3	2	894	1490	639	5.8		1490
Waler	12x12	3.5	3.5	2	894	1788	511	7.0		1788
Block	4x12x12	10	1	1	894	89	89	0.4		89
	inspection date		9/21/96							
Section	2	beg sta =	894	end sta =	1374	NAVSTA		M-3 through M-4		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3.5	1	1	480	137	137		137	393
Chock	8x12	3.5	2.3	2	480	800	343	5.8		2290
Waler	12x12	3.5	3.5	2	480	960	274	7.0		2748
Block	4x12x12	10	1	1	480	48	48	0.4		137
	inspection date		9/21/96							
Section	summary	0- 2234 feet		NAVSTA	M-1 through M-4					
		amount of waterfront using timber fenders (lf) =				1374				
Timber Material	size/dia.	totals								
	(inches)	(num & lf)								
Fender Pile	18	393								
Chock	8x12	2290								
Waler	12x12	2748								
Block	4x12x12	137								

	inspection date		9/22/96							
Section	1	beg sta =	0	end sta =	73	SUBASE		S-1A		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	4.5	1	1	73	16	16		16	16
Chock	8x12	4.5	3.3	2	73	127	38	7.8		127
Waler	12x12	4.5	4.5	2	73	146	32	9.0		146
Block	4x12x12	5	1	1	73	15	15	0.9		15
	inspection date		9/22/96							
Section	2	beg sta =	73	end sta =	1100	SUBASE	S-1A through S-1B			
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	1027	205	205		189	206
Chock	8x12	5	3.8	2	1027	1814	473	8.8		1941
Waler	12x12	5	5	2	1027	2054	411	10.0		2200
Block	4x12x12	5	1	1	1027	205	205	1.0		220
	inspection date		9/22/96							
Section	summary	0- 1100 feet		SUBASE	S-1A through S-1B					
		amount of waterfront using timber fenders (lf) =				1100				
Timber Material	**size/dia.**	**totals**								
	(inches)	(num & lf)								
Fender Pile	18	206								
Chock	8x12	1941								
Waler	12x12	2200								
Block	4x12x12	220								

	inspection date		9/22/96							
Section	**1**	**beg sta =**	**0**	**end sta =**	**285**	**SUBASE**		**S4**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3	1	1	285	95	101		101	101
Chock	8x12	3	1.8	1	285	174	95	1.7		174
Waler	12x12	3	3	1	285	285	95	3.0		285
Block	4x12x12	8.5	1	1	285	34	34	0.3		34
Section	**2**	**beg sta =**	**285**	**end sta =**	**326**	**SUBASE**		**S-4**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3	1	1	41	14	14		14	115
Chock	8x12	3	1.8	1	41	25	14	1.8		199
Waler	12x12	3	3	1	41	41	14	3.0		326
Block	4x12x12	8.5	1	1	41	5	5	0.4		38
Section	**1**	**beg sta =**	**326**	**end sta =**	**440**	**SUBASE**		**S-5**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3	1	1	114	38	38		38	153
Chock	8x12	3	1.8	1	114	70	38	1.8		269
Waler	12x12	3	3	1	114	114	38	3.0		440
Block	4x12x12	10	1	1	114	11	11	0.3		50

Section	**2**	**beg sta =**	**440**	**end sta =**	**497**	**SUBASE**		**S-5**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	1.5	1	1	57	38	38		38	191
Chock	8x12	1.5	0.3	1	57	13	38	0.3		282
Waler	12x12	1.5	1.5	1	57	57	38	1.5		497
Block	4x12x12	4	1	1	57	14	14	0.4		64
Section	**3**	**beg sta =**	**497**	**end sta =**	**668**	**SUBASE**		**S-5**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5.67	1	1	171	30	30		30	221
Chock	8x12	5.67	4.5	1	171	136	30	4.5		417
Waler	12x12	5.67	5.67	1	121	121	21	4.0		618
Block	4x12x12	10	1	1	121	12	12	0.4		76
Section	**summary**	**0 -**	**668**	**feet**	**SUBASE**	**S-4 through S-5**				
		amount of waterfront using timber fenders (lf) =				**668**				
Timber Material	**size/dia.**	**totals**								
	(inches)	(num & lf)								
Fender Pile	18	221								
Chock	8x12	417								
Waler	12x12	618								
Block	4x12x12	76								

	inspection date		**9/22/96**							
Section	**1**	**beg sta =**	**0**	**end sta =**	**80**	**SUBASE**		**S8**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	6	1	1	80	13	19		19	19
Chock	8x12	6	4.8	1	80	64	13	3.3		64
Waler	12x12	6	6		80					
Block	4x12x12	6	1	1	80	13	13	0.7		13
	inspection date		**9/22/96**							
Section	**2**	**beg sta =**	**80**	**end sta =**	**340**	**SUBASE**		**S-8**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3.33	1	1	260	78	78		78	97
Chock	8x12	3.33	2.2	1	260	169	78	2.2		233
Waler	12x12	3.33	3.33	1	260	260	78	3.3		260
Block	4x12x12	8.75	1	1	260	30	30	0.4		43
	inspection date		**9/22/96**							
Section	**3**	**beg sta =**	**340**	**end sta =**	**381**	**SUBASE**		**S-8**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3.33	1	1	41	12	12		12	110
Chock	8x12	3.33	2.2	1	41	27	12	2.2		260
Waler	12x12	3.33	3.33	1	41	41	12	3.3		301
Block	4x12x12	8.75	1	1	41	5	5	0.4		48

	inspection date		9/22/96							
Section	**1**	**beg sta =**	**381**	**end sta =**	**419**	**SUBASE**		**S-9**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	38	8	8		8	117
Chock	8x12	5	3.8	1	38	29	8	3.8		289
Waler	12x12	5	5	1	38	38	8	5.0		339
Block	4x12x12	9	1	1	38	4	4	0.6		52
	inspection date		**9/22/96**							
Section	**2**	**beg sta =**	**419**	**end sta =**	**506**	**SUBASE**		**S-9**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	2	1	1	87	44	44		44	161
Chock	8x12	2	0.8	1	87	36	44	0.8		325
Waler	12x12	2	2	1	87	87	44	2.0		426
Block	4x12x12	9	1	1	87	10	10	0.2		62
	inspection date		**9/22/96**							
Section	**3**	**beg sta =**	**506**	**end sta =**	**555**	**SUBASE**		**S-9**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	6	1	1	49	8	8		8	169
Chock	8x12	6	4.8	1	49	39	8	4.8		365
Waler	12x12	6	6	1	49	49	8	6.0		475
Block	4x12x12	9	1	1	49	5	5	0.7		67

	inspection date		9/22/96							
Section	**4**	beg sta =	555	end sta =	646	SUBASE		S-9		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	6	1	1	91	15	15		15	184
Chock	8x12	6	4.8	1	91	73	15	4.8		438
Waler	12x12	6	6	1	91	91	15	6.0		566
Block	4x12x12	9	1	1	91	10	10	0.7		77
	inspection date		9/22/96							
Section	**5**	beg sta =	646	end sta =	763	SUBASE		S-9		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	6	1	1	117	20	20		20	204
Chock	8x12	6	4.8	1	117	94	20	4.8		532
Waler	12x12	6	6	1	117	117	20	6.0		683
Block	4x12x12	9	1	1	117	13	13	0.7		90
	inspection date		9/22/96							
Section	**summary**	0 -	506	feet	SUBASE	S-4 through S-5				
		amount of waterfront using timber fenders (lf) =				763				
Timber Material	**size/dia.**	**totals**								
	(inches)	(num & lf)								
Fender Pile	18	204								
Chock	8x12	532								
Waler	12x12	683								
Block	4x12x12	90								

	inspection date		9/22/96							
Section	**1**	**beg sta =**	**0**	**end sta =**	**65**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	6	1	1	65	11	17		17	17
Chock	8x12	6	4.8	1	65	52	11	3.1		52
Waler	12x12	6	6		65					
Block	4x12x12	9	1	1	65	7	7	0.4		7
	inspection date		9/22/96							
Section	**2**	**beg sta =**	**65**	**end sta =**	**145**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	2	1	1	80	40	40		40	57
Chock	8x12	2	0.8	2	80	113	136	2.8		166
Waler	12x12	2	2	2	80	160	80	4.0		160
Block	4x12x12	9	1	2	80	18	18	0.4		25
	inspection date		9/22/96							
Section	**3**	**beg sta =**	**145**	**end sta =**	**253**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	2	1	1	108	54	54		54	111
Chock	8x12	2	0.8	2	108	153	184	2.8		319
Waler	12x12	2	2	2	108	216	108	4.0		376
Block	4x12x12	9	1	2	108	24	24	0.4		49

Section	4	beg sta =	253	end sta =	593	SUBASE		S-10 through S-14		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3	1	1	340	113	113		113	224
Chock	8x12	3	1.8	1	340	208	113	1.8		526
Waler	12x4	3	3	1	340	340	113	3.0		716
Block	4x12x12	9	1	1	340	38	38	0.3		87
Section	**5**	**beg sta =**	**593**	**end sta =**	**621**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	7.75	1	1	28	4	4		4	228
Chock	8x12	7.75	6.6	1	28	24	4	6.6		526
Waler	12x12	7.75	7.75	1	28	28	4	7.8		716
Block	4x12x12	7.75	1	1	28	4	4	1.0		87
Section	**6**	**beg sta =**	**621**	**end sta =**	**704**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	4	1	1	83	21	21		21	249
Chock	8x12	4	2.8	1	83	59	21	2.8		585
Waler	12x12	4	4	1	83	83	21	4.0		799
Block	4x12x12	9	1	1	83	9	9	0.4		96

Section	7	beg sta =	704	end sta =	789	SUBASE		S-10 through S-14		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	6	1	1	85	14	14		14	263
Chock	8x12	6	4.8	1	85	68	14	4.8		654
Waler	12x12	6	6	1	85	85	14	6.0		884
Block	4x12x12	9	1	1	85	9	9	0.7		105
Section	**8**	**beg sta =**	**789**	**end sta =**	**871**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	82	16	16		16	279
Chock	8x12	5	3.8	1	82	63	16	3.8		717
Waler	12x12	5	5	1	82	82	16	5.0		966
Block	4x12x12	6	1	1	82	14	14	0.8		119
Section	**9**	**beg sta =**	**871**	**end sta =**	**924**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	2	1	1	53	27	27		27	306
Chock	8x12	2	0.8	1	53	22	27	0.8		739
Waler	12x12	2	2	1	53	53	27	2.0		1019
Block	4x12x12	6	1	1	53	9	9	0.3		128

Section	10	beg sta =	924	end sta =	987	SUBASE		S-10 through S-14		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	63	13	13		13	318
Chock	8x12	5	3.8	1	63	48	13	3.8		787
Waler	12x12	5	5	1	63	63	13	5.0		1082
Block	4x12x12	6	1	1	63	11	11	0.8		138
Section	**11**	**beg sta =**	**987**	**end sta =**	**1095**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	3.5	1	1	108	31	31		31	349
Chock	8x12	3.5	2.3	1	108	72	31	2.3		859
Waler	12x12	3.5	3.5	1	108	108	31	3.5		1190
Block	4x12x12	6	1	1	108	18	18	0.6		156
Section	**12**	**beg sta =**	**1095**	**end sta =**	**1142**	**SUBASE**		**S-10 through S-14**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	2	1	1	47	24	24		24	373
Chock	8x12	2	0.8	1	47	20	24	0.8		879
Waler	12x12	2	2	2	47	94	47	4.0		1284
Block	4x12x12	6	1	2	47	16	16	0.7		172

Section	13	beg sta =	1142	end sta =	1219	SUBASE		S-10 through S-14		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	77	15	15		15	388
Chock	8x12	5	3.8	1	77	59	15	3.8		938
Waler	12x4	5	5	2	77	154	31	10.0		1438
Block	4x12x12	5	1	2	77	31	31	2.0		203
Section	14	beg sta =	1219	end sta =	1277	SUBASE		S-10 through S-14		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	58	12	12		12	400
Chock	8x12	5	3.8	1	58	44	12	3.8		982
Waler	12x12	5	5	2	58	116	23	10.0		1554
Block	4x12x12	5	1	2	58	23	23	2.0		226
Section	summary	0 -	1277	feet		SUBASE	S-10 t	S-10 through S-14		
		amount of waterfront using timber fenders (lf) =				1277				
Timber Material	size/dia.	totals								
	(inches)	(num & lf)								
Fender Pile	18	400								
Chock	8x12	982								
Waler	12x12	1060								
Waler	12X4	494								
Block	4x12x12	226								

Section	13	beg sta =	1142	end sta =	1219	SUBASE		S-10 through S-14		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	77	15	15		15	388
Chock	8x12	5	3.8	1	77	59	15	3.8		938
Waler	12x4	5	5	2	77	154	31	10.0		1438
Block	4x12x12	5	1	2	77	31	31	2.0		203
Section	14	beg sta =	1219	end sta =	1277	SUBASE		S-10 through S-14		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	58	12	12		12	400
Chock	8x12	5	3.8	1	58	44	12	3.8		982
Waler	12x12	5	5	2	58	116	23	10.0		1554
Block	4x12x12	5	1	2	58	23	23	2.0		226
Section	summary	0 -	1277	feet		SUBASE	S-10 t	S-10 through S-14		
		amount of waterfront using timber fenders (lf) =				1277				
Timber Material	size/dia.	totals								
	(inches)	(num & lf)								
Fender Pile	18	400								
Chock	8x12	982								
Waler	12x12	1060								
Waler	12X4	494								
Block	4x12x12	226								

	inspection date		**9/27/96**							
Section	**1**	**beg sta =**	**0**	**end sta =**	**166**	**NAVSTA**		**S-15**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	166	33	39		39	39
Chock	8x12	5	3.8	1	166	127	33	3.2		127
Waler	12x12	5	5	1	166	166	33	5.0		166
Block	4x12x12	5	1	1	166	33	33	0.8		33
	inspection date		**9/27/96**							
Section	**1**	**beg sta =**	**624**	**end sta =**	**1082**	**NAVSTA**		**S-16**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	458	92	92		92	131
Chock	8x12	5	3.8	2	458	809	211	8.8		936
Waler	12x12	5	5	2	458	916	183	10.0		1082
Block	4x12x12	5	1	2	458	183	183	2.0		216
	inspection date		**9/27/96**							
Section	**2**	**beg sta =**	**1082**	**end sta =**	**1248**	**NAVSTA**		**S-16**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	166	33	33		33	164
Chock	8x12	5	3.8	1	166	127	33	3.8		1064
Waler	12x4	5	5	1	166	166	33	5.0		1248
Block	4x12x12	9	1	1	166	18	18	0.6		235

	inspection date		9/27/96							
Section	**17**	**beg sta =**	**1248**	**end sta =**	**1704**	**NAVSTA**		**S-17**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	456	91	91		91	255
Chock	8x12	5	3.8	1	456	350	91	3.8		1413
Waler	12x12	5	5	1	456	456	91	5.0		1704
Block	4x12x12	5	1	1	456	91	91	1.0		326
	inspection date		9/27/96							
Section	**1**	**beg sta =**	**1704**	**end sta =**	**2160**	**NAVSTA**		**S-18**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	456	91	91		91	346
Chock	8x12	5	3.8	1	456	350	91	3.8		1763
Waler	12x12	5	5	1	456	456	91	5.0		2160
Block	4x12x12	5	1	1	456	91	91	1.0		417
	inspection date		9/27/96							
Section	**2**	**beg sta =**	**2160**	**end sta =**	**2326**	**NAVSTA**		**S-18**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	166	33	33		33	380
Chock	8x12	5	3.8	1	166	127	33	3.8		1890
Waler	12x12	5	5	1	166	166	33	5.0		2326
Block	4x12x12	5	1	1	166	33	33	1.0		450

	inspection date		**9/27/96**							
Section	**1**	**beg sta =**	**2326**	**end sta =**	**2906**	**NAVSTA**		**S-19 through S-21**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	580	116	116		122	502
Chock	8x12	5	3.8	1	580	445	116	3.8		2335
Waler	12x12	5	5	1	580	580	116	5.0		2906
Block	4x12x12	5	1	1	580	116	116	1.0		566
	inspection date		**9/27/96**							
Section	**2**	**beg sta =**	**2906**	**end sta =**	**3111**	**NAVSTA**		**S-19 through S-21**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	205	41	41		41	543
Chock	8x12	5	3.8	1	205	157	41	3.8		2492
Waler	12x12	5	5	1	205	205	41	5.0		3111
Block	4x12x12	5	1	1	205	41	41	1.0		607
	inspection date		**9/27/96**							
Section	**3**	**beg sta =**	**3111**	**end sta =**	**3966**	**NAVSTA**		**S-19 through S-21**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	855	171	171		171	714
Chock	8x12	5	3.8	1	855	656	171	3.8		3147
Waler	12x12	5	5	1	855	855	171	5.0		3966
Block	4x12x12	5	1	1	855	171	171	1.0		778

	inspection date		9/27/96							
Section	4	beg sta =	3966	end sta =	4106	NAVSTA		S-19 through S-21		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	140	28	28		28	742
Chock	8x12	5	3.8	1	140	107	28	3.8		3255
Waler	12x12	5	5	1	140	140	28	5.0		4106
Block	4x12x12	5	1	1	140	28	28	1.0		806
	inspection date		9/27/96							
Section	5	beg sta =	4106	end sta =	4576	SUBASE		S-19 through S-21		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	470	94	94		94	836
Chock	8x12	5	3.8	1	470	360	94	3.8		3615
Waler	12x12	5	5	2	470	940	188	10.0		5046
Block	4x12x12	5	1	2	470	188	188	2.0		994
	inspection date		9/27/96							
Section	summary	0 -	4576	feet	SUBASE &	NAVSTA		S-15 through S-21		
		amount of waterfront using timber fenders (lf) =				4118				
Timber Material	size/dia.	totals								
	(inches)	(num & lf)								
Fender Pile	18	836								
Chock	8x12	3615								
Waler	12x12	5046								
Block	4x12x12	994								

	inspection date		9/27/96							
Section	1	beg sta =	0	end sta =	1075	FISC		K-3 through K-5		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	1075	215	221		221	221
Chock	8x12	5	3.8	1	1075	824	215	3.7		824
Waler	12x12	5	5	1	1075	1075	215	5.0		1075
Block	4x12x12	5	1	1	1075	215	215	1.0		215

	inspection date		9/27/96							
Section	1	beg sta =	1075	end sta =	1481	FISC		K-6		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	406	81	81		81	302
Chock	8x12	5	3.8	1	406	311	81	3.8		1135
Waler	12x12	5	5	1	406	406	81	5.0		1481
Block	4x12x12	5	1	1	406	81	81	1.0		296

	inspection date		9/27/96							
Section	1	beg sta =	1481	end sta =	2116	FISC		K-7		
Timber Material	size/dia.	dist. on ctr.	amt/length	number	Sect. length	totals	total	breakdwn	total piles	run totals
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	635	127	127		134	436
Chock	8x12	5	3.8	2	635	1122	293	8.8		2257
Waler	12x12	5	5	2	635	1270	254	10.0		2751
Block	4x12x12	5	1	2	635	254	254	2.0		550

	inspection date		9/27/96							
Section	**1**	**beg sta =**	**2116**	**end sta =**	**2873**	FISC		K-8		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	757	151	151		151	588
Chock	8x12	5	3.8	1	757	580	151	3.8		2838
Waler	12x4	5	5	1	757	757	151	5.0		3508
Block	4x12x12	5	1	1	757	151	151	1.0		702
	inspection date		9/27/96							
Section	**1**	**beg sta =**	**2873**	**end sta =**	**3226**	FISC		K-9		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	353	71	71		71	658
Chock	8x12	5	3.8	1	353	271	71	3.8		3108
Waler	12x12	5	5	1	353	353	71	5.0		3861
Block	4x12x12	5	1	1	353	71	71	1.0		772
	inspection date		9/27/96							
Section	**1**	**beg sta =**	**3226**	**end sta =**	**4251**	FISC		K-10		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	1025	205	205		205	863
Chock	8x12	5	3.8	1	1025	786	205	3.8		3894
Waler	12x12	5	5	1	1025	1025	205	5.0		4886
Block	4x12x12	5	1	1	1025	205	205	1.0		977

	inspection date		9/27/96		
Section	summary	0 -	4251	feet	FISC	K-3 through K-10
		amount of waterfront using timber fenders (lf) = 4251			
Timber Material	size/dia.	totals			
	(inches)	(num & lf)			
Fender Pile	18	863			
Chock	8x12	3894			
Waler	12x12	4886			
Block	4x12x12	977			

	inspection date		**9/28/96**							
Section	**1**	**beg sta =**	**0**	**end sta =**	**575**	**NAVSTA**		**F-1**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5.5	1	1	575	105	111		191	191
Pile cluster	14	50	7	7	575	12	81			
Chock	8x12	5.5	4.3	1	575	453	105	4.1		453
Waler	12x12	5.5	5.5	1	575	575	105	5.5		575
Block	4x12x12	6.5	1	1	575	88	88	0.8		88
	inspection date		**9/28/96**							
Section	**1**	**beg sta =**	**575**	**end sta =**	**645**	**NAVSTA**		**F-9**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	70	14	14		14	205
Chock	8x12	5	3.8	1	70	54	14	3.8		507
Waler	12x12	5	5	1	70	70	14	5.0		645
Block	4x12x12	3	1	1	70	23	23	1.7		112
	inspection date		**9/28/96**							
Section	**2**	**beg sta =**	**645**	**end sta =**	**942**	**NAVSTA**		**F-9**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	297	59	59		66	271
Chock	8x12	5	3.8	2	297	525	137	8.8		1031
Waler	12x12	5	5	2	297	594	119	10.0		1239
Block	4x12x12	6	1	2	297	99	99	1.7		211

	inspection date		**9/28/96**							
Section	**1**	**beg sta =**	**942**	**end sta =**	**1232**	**NAVSTA**		**F-10**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	290	58	58		58	329
Chock	8x12	5	3.8	1	290	222	58	3.8		1254
Waler	12x4	5	5	1	290	290	58	5.0		1529
Block	4x12x12	5	1	1	290	58	58	1.0		269
	inspection date		**9/28/96**							
Section	**2**	**beg sta =**	**1232**	**end sta =**	**1732**	**NAVSTA**		**F-10**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	500	100	100		100	429
Chock	8x12	5	3.8	1	500	383	100	3.8		1637
Waler	12x12	5	5	1	500	500	100	5.0		2029
Block	4x12x12	6	1	1	500	83	83	0.8		352
	inspection date		**9/28/96**							
Section	**1**	**beg sta =**	**1732**	**end sta =**	**1787**	**NAVSTA**		**F-12 through F-13**		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	55	11	11		11	440
Chock	8x12	5	3.8		55					1637
Waler	12x12	5	5	1	55	55	11	5.0		2084
Block	4x12x12	5	1	1	55	11	11	1.0		363

	inspection date		9/28/96							
Section	**2**	**beg sta =**	**1787**	**end sta =**	**3167**	NAVSTA		F-12 through F-13		
Timber Material	**size/dia.**	**dist. on ctr.**	**amt/length**	**number**	**Sect. length**	**totals**	**total**	**breakdwn**	**total piles**	**run totals**
	(inches)	(feet)	on ctr.	on ctr.	(feet)	(num & lf)	count	(lf/fend pile)	(for section)	(num & lf)
Fender Pile	14	5	1	1	1380	276	276		276	716
Chock	8x12	5	3.8	1	1380	1058	276	3.8		2695
Waler	12x12	5	5	1	1380	1380	276	5.0		3464
Block	4x12x12	5	1	1	1380	276	276	1.0		639
	inspection date		9/28/96							
Section	**summary**	**0 -**	**3167**	**feet**	**FISC**			**F-12 through F-13**		
		amount of waterfront using timber fenders (lf) =				3167				
Timber Material	**size/dia.**	**totals**								
	(inches)	(num & lf)								
Fender Pile	18	716								
Chock	8x12	2695								
Waler	12x12	3464								
Block	4x12x12	639								

Timber Summary Summary

inspection dates	9/21/96	9/22/96	9/27/96

	(lf)	(mi)
surveyed amount of waterfront using timber fenders (lf) =	19,643	3.7

Timber Material	size/dia. (inches)	totals (num & lf)	totals (num & mi)
Fender Pile	14-18	4,713	4,713
Waler	12x12	23,159	4.4
Chock	8x12	18,588	3.5
Block	4x12x12	3,921	0.7

Appendix B

Fender Replacement Activity Cost Estimation

Timber Pile Maintenance Costs

assume typical: single waler, chock; piles & blocks @ 5' on center

assume number of piles replaced = 10

Material	cost, ea.	cost/lf	length (lf)	number per sect.	cost totals	
pile, timber - 65'	886.28	13.64	65		8,862.80	
waler, 12"x12"x20'	267.84	13.39	5		669.60	
chock, 8"x12"x20'	208.92	10.45	3.8		400.43	
block, 4"x12"x20'	147.96	7.40	1		73.98	10,006.81
bolt, galvanized, 1"x29" (w/ nut)	12.10			3	363.00	
bolts, 'T', 1"x17"	8.80			1	88.00	
washer, 1"	3.60			4	144.00	
staples, 3/8"x1"x3" (2-per pile)	1.72			2	34.40	
line, manila, 3/4" (6'-per pile)		0.53	6		31.80	661.20
sub total					**10,668.01**	10668.01

Activity # 1 — Draw, Load, Transport Materials

Draw, Load, Transport Materials	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
operator, specific work straight time	51.37	2	102.74	4.00	410.96
truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
semitrailer lowbed 2 axle 35T	2.50	1	6.25	4.00	25.00
driver, specific work straight time	51.37	1	51.37	4.00	205.48
subtotal					**677.04**

Activity # 2 — Staging Materials

Staging Materials	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
operator, specific work straight time	51.37	1	51.37	4.00	205.48
truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
semitrailer lowbed 2 axle 35T	2.50	1	6.25	4.00	25.00
driver, specific work straight time	51.37	1	51.37	4.00	205.48
subtotal					**471.56**

Activity # 3 — Mobilization

Mobilization	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
crane truck mtd 2-eng prt 35 ton cap	47.78	1	47.78	4.00	191.12
operator, specific work straight time	51.37	1	51.37	4.00	205.48
truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
semitrailer lowbed 2 axle 35T	2.50	1	6.25	4.00	25.00
driver, specific work straight time	51.37	1	51.37	4.00	205.48
compressor air 600 cfm portable	6.15	1	6.15	4.00	24.60
hammer pile driver diesel	1.00	1	1.00	4.00	4.00
hammer pile extractor diesel	1.00	1	1.00	4.00	4.00
wharf builder, specific work straight time	51.37	1	51.37	4.00	205.48
subtotal					**884.76**

Activity # 4 — Demolition

Demolition	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
crane truck mtd 2-eng prt 35 ton cap	47.78	1	47.78	8.00	382.24
operator, specific work straight time	51.37	1	51.37	8.00	410.96
compressor air 600 cfm portable	6.15	1	6.15	8.00	49.20
hammer pile extractor diesel	1.00	1	1.00	8.00	8.00
wharf builder, specific work straight time	51.37	4	205.48	8.00	1,643.84
subtotal					**2,494.24**

Activity #	5	Cosnstruction	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		crane truck mtd 2-eng prt 35 ton cap	47.78	1	47.78	8.00	382.24
		operator, specific work straight time	51.37	1	51.37	8.00	410.96
		compressor air 600 cfm portable	6.15	1	6.15	8.00	49.20
		hammer pile driver diesel	1.00	1	1.00	8.00	8.00
		wharf builder, specific work straight time	51.37	4	205.48	8.00	1,643.84
		subtotal					**2,494.24**

Activity #	6	Load, Transport Debris to Pearl City	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
		operator, specific work straight time	51.37	2	102.74	4.00	410.96
		truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
		semitrailer rear dump 34 cuyd	6.00	1	6.00	4.00	24.00
		driver, specific work straight time	51.37	1	51.37	4.00	205.48
		subtotal					**676.04**

Activity #	7	Prep Debris @ Pearl City for Dump	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
		operator, specific work straight time	51.37	2	102.74	4.00	410.96
		truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
		semitrailer rear dump 34 cuyd	6.00	1	6.00	4.00	24.00
		driver, specific work straight time	51.37	1	51.37	4.00	205.48
		wharf builder, specific work straight time	51.37	1	51.37	4.00	205.48
		subtotal					**881.52**

Activity #	8	Load, Transport Debris to Dump	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
		operator, specific work straight time	51.37	2	102.74	4.00	410.96
		truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
		semitrailer rear dump 34 cuyd	6.00	1	6.00	4.00	24.00
		driver, specific work straight time	51.37	1	51.37	4.00	205.48
		subtotal					**676.04**

Activity #	9	Dump Cost	weight per lf	cost per ton	cost per lb.	length (lf)	cost totals
		pile, timber	45	57.00	0.03	650	833.63
		waler, 12"x12"	42	57.00	0.03	50	59.99
		chock, 8"x12"	28	57.00	0.03	38	30.73
		block, 4"x12"	14	57.00	0.03	10	4.02
		sub total					**928.37**

Timber Pile Fender Life Cycle Cost Summary

Total Material Costs	10,668
Total Construction Costs	7,698
Total Disposal Costs	2,486
Total Cost For 10 Piles	**20,852**

Seapile Maintenance Costs - No Recycling Assumed

assume typical: single waler, chock; piles & blocks @ 5' on center

assume number of piles replaced = 10

Material	**cost, ea.**	**cost/lf**	**length (lf)**	**number per sect.**	**cost totals**	
pile, plastic - 65' w/ 8-1.25" fibr rebar	2,925.00	45.00	65		29,250.00	
waler, 12"x12"x20' w/ 8-1.0" fibr rebar	900.00	45.00	5		2,250.00	
chock, 8"x12"x20'	800.00	40.00	3.9		1,566.67	
block, 4"x12"x20'	360.00	18.00	1		180.00	33,246.67
bolt, galvanized, 1"x29" (w/ nut)	12.10			3	363.00	
bolts, 'T', 1"x17"	8.80			1	88.00	
washer, 1"	3.60			4	144.00	
staples, 3/8"x1"x3" (2-per pile)	1.72			2	34.40	
line, manila, 3/4" (6'-per pile)		0.53	6		31.80	661.20
sub total					**33,907.87**	**33,907.87**

Activity # 1 Draw, Load, Transport Materials

	cost per hr.	**num. req.**	**sub. tot. cost**	**duration (hrs.)**	**cost totals**
truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
operator, specific work straight time	51.37	2	102.74	4.00	410.96
truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
semitrailer lowbed 2 axle 35T	2.50	1	6.25	4.00	25.00
driver, specific work straight time	51.37	1	51.37	4.00	205.48
subtotal					**677.04**

Activity # 2 Staging Materials

	cost per hr.	**num. req.**	**sub. tot. cost**	**duration (hrs.)**	**cost totals**
truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
operator, specific work straight time	51.37	1	51.37	4.00	205.48
truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
semitrailer lowbed 2 axle 35T	2.50	1	6.25	4.00	25.00
driver, specific work straight time	51.37	1	51.37	4.00	205.48
subtotal					**471.56**

Activity # 3 Mobilization

	cost per hr.	**num. req.**	**sub. tot. cost**	**duration (hrs.)**	**cost totals**
crane truck mtd 2-eng prt 35 ton cap	47.78	1	47.78	4.00	191.12
operator, specific work straight time	51.37	1	51.37	4.00	205.48
truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
semitrailer lowbed 2 axle 35T	2.50	1	6.25	4.00	25.00
driver, specific work straight time	51.37	1	51.37	4.00	205.48
compressor air 600 cfm portable	6.15	1	6.15	4.00	24.60
hammer pile driver diesel	1.00	1	1.00	4.00	4.00
hammer pile extractor diesel	1.00	1	1.00	4.00	4.00
wharf builder, specific work straight time	51.37	1	51.37	4.00	205.48
subtotal					**884.76**

Activity # 4 Demolition

	cost per hr.	**num. req.**	**sub. tot. cost**	**duration (hrs.)**	**cost totals**
crane truck mtd 2-eng prt 35 ton cap	47.78	1	47.78	8.00	382.24
operator, specific work straight time	51.37	1	51.37	8.00	410.96
compressor air 600 cfm portable	6.15	1	6.15	8.00	49.20
hammer pile extractor diesel	1.00	1	1.00	8.00	8.00
wharf builder, specific work straight time	51.37	4	205.48	8.00	1643.84
subtotal					**2494.24**

Activity #	5	Cosnstruction	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		crane truck mtd 2-eng prt 35 ton cap	47.78	1	47.78	8.00	382.24
		operator, specific work straight time	51.37	1	51.37	8.00	410.96
		compressor air 600 cfm portable	6.15	1	6.15	8.00	49.20
		hammer pile driver diesel	1.00	1	1.00	8.00	8.00
		wharf builder, specific work straight time	51.37	4	205.48	8.00	1643.84
		subtotal					**2494.24**

Activity #	6	Load, Transport Debris to Pearl City	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
		operator, specific work straight time	51.37	2	102.74	4.00	410.96
		truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
		semitrailer rear dump 34 cuyd	6.00	1	6.00	4.00	24.00
		driver, specific work straight time	51.37	1	51.37	4.00	205.48
		subtotal					**676.04**

Activity #	7	Prep Debris @ Pearl City for Dump	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
		operator, specific work straight time	51.37	2	102.74	4.00	410.96
		truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
		semitrailer rear dump 34 cuyd	6.00	1	6.00	4.00	24.00
		driver, specific work straight time	51.37	1	51.37	4.00	205.48
		wharf builder, specific work straight time	51.37	1	51.37	4.00	205.48
		subtotal					**881.52**

Activity #	8	Load, Transport Debris to Dump	cost per hr.	num. req.	sub. tot. cost	duration (hrs.)	cost totals
		truck forklift 6000 180" gas	4.00	1	4.00	4.00	16.00
		operator, specific work straight time	51.37	2	102.74	4.00	410.96
		truck tractor DED 32000 GVW Min	4.90	1	4.90	4.00	19.60
		semitrailer rear dump 34 cuyd	6.00	1	6.00	4.00	24.00
		driver, specific work straight time	51.37	1	51.37	4.00	205.48
		subtotal					**676.04**

Activity #	9	Dump Cost	weight per lf	cost per ton	cost per lb.	length (lf)	cost totals
		pile, plastic	33	57.00	0.03	650	611.33
		waler, 12"x12"	41	57.00	0.03	50	58.43
		chock, 8"x12"	32	57.00	0.03	39	35.72
		block, 4"x12"	16	57.00	0.03	10	4.56
		sub total					**710.03**

Plastic Pile Fender Life Cycle Cost Summary

Total Material Costs	33,908
Total Construction Costs	7,698
Total Disposal Costs	2,268
Total Cost For 10 Piles	**43,873**

Appendix C

Fender Maintenance Economic Analysis

Timber

pile life	**3**
number of piles estimated	10
inflation rate (i)	**3.70%**
timber material inflation rate (j)	**14.87%**
timber material costs per pile (M)	**1,000.68**
other material costs per pile	66.12
total material costs per pile	1,067
total construction costs per pile	770
total disposal costs per pile	249
total disp,const,other costs per pile (C)	**1,085**
total cost per pile	2,085

replacement year	$P = C + \frac{M(1+j)^n}{(1+i)^n}$	Total Cost (cum P)
0	2,085	2,085
3	2,445	4,530
6	2,933	7,463
9	3,597	**11,060**
12	4,500	15,560
15	5,727	21,287
18	7,394	**28,681**
21	9,660	38,341
24	12,741	51,082
27	16,928	**68,010**
30	22,619	90,629
33	30,354	120,983
36	40,868	161,850
39	55,158	**217,008**
42	74,581	291,589
45	100,981	392,570
48	136,864	**529,433**

Timber

pile life	**5**
number of piles estimated	10
inflation rate (i)	**3.70%**
timber material inflation rate (j)	**14.87%**
timber material costs per pile (M)	**1,000.68**
other material costs per pile	66.12
total material costs per pile	1,067
total construction costs per pile	770
total disposal costs per pile	249
total disp,const,other costs per pile (C)	**1,085**
total cost per pile	2,085

replacement year	$P = C + \frac{M(1+j)^n}{(1+i)^n}$	Total Cost (cum P)
0	2,085	2,085
5	2,753	**4,839**
10	3,868	8,706
15	5,727	**14,433**
20	8,826	23,260
25	13,996	**37,256**
30	22,619	59,875
35	36,999	**96,874**
40	60,982	157,856
45	100,981	**258,837**

Plastic (no recycle)

pile life	**10**
number of piles estimated	10
inflation rate (i)	**0.00%**
material inflation rate (j)	**0.00%**
plastic material costs per pile (M)	**3,325**
other material costs per pile	66.12
total material costs per pile	3,391
total construction costs per pile	770
total disposal costs per pile	227
total disp,const,other costs per pile (C)	**1,063**
total cost per pile	4,387

replacement year	$P = C + \frac{M(1+j)^n}{(1+i)^n}$	Total Cost (cum P)
0	4,387	4,387
10	4,387	8,775
20	4,387	13,162
30	4,387	17,549
40	4,387	21,937

	Plastic (no recycle)		Plastic (recycle)		Plastic (recycle)
pile life	**25**	**pile life**	**10**	**pile life**	**25**
number of piles estimated	10	number of piles estimated	10	number of piles estimated	10
inflation rate (i)	**0.00%**	**inflation rate (i)**	**0.00%**	**inflation rate (i)**	**0.00%**
material inflation rate (j)	0.00%	material inflation rate (j)	0.00%	material inflation rate (j)	0.00%
plastic material costs per pile (M)	**3,325**	**plastic material costs per pile (M)**	**3,325**	**plastic material costs per pile (M)**	**3,325**
other material costs per pile	66.12	other material costs per pile	66.12	other material costs per pile	66.12
total material costs per pile	3,391	total material costs per pile	3,391	total material costs per pile	3,391
total construction costs per pile	770	total construction costs per pile	770	total construction costs per pile	770
total disposal costs per pile	227	total disposal costs per pile	0	total disposal costs per pile	0
total disp,const,other costs per pile (C)	1,063	**total disp,const,other costs per pile (C)**	836	**total disp,const,other costs per pile (C)**	836
total cost per pile	4,387	total cost per pile	4,161	total cost per pile	4,161

replacement year	**$P = C + M\frac{(1+j)^n}{(1+i)^n}$**	**Total Cost (cum P)**	**replacement year**	**$P = C + M\frac{(1+j)^n}{(1+i)^n}$**	**Total Cost (cum P)**	**replacement year**	**$P = C + M\frac{(1+j)^n}{(1+i)^n}$**	**Total Cost (cum P)**
0	4,387	4,387	0	4,161	4,161	0	4,161	4,161
25	4,387	8,775	10	4,161	8,322	25	4,161	8,322
			20	4,161	12,483			
			30	4,161	16,644			
			40	4,161	20,805			

plot - 10 pile job (no recycle)

Remaining Design Life	timber 3 yr	timber 5 yr	plastic 10 yr	plastic 25 yr
10	11,060	4,839	4,387	4,387
20	28,681	14,433	8,775	4,387
30	68,010	37,256	13,162	8,775
40	217,008	96,874	17,549	8,775
50	529,433	258,837	21,937	8,775

plot - 10 pile job (recycle)

Remaining Design Life	timber 3 yr	timber 5 yr	plastic 10 yr	plastic 25 yr
10	11,060	4,839	4,161	4,161
20	28,681	14,433	8,322	4,161
30	68,010	37,256	12,483	8,322
40	217,008	96,874	16,644	8,322
50	529,433	258,837	20,805	8,322

plot - 10 pile job (no recycle)

Remaining Design Life	timber 3 yr	timber 5 yr	plastic 10 yr	plastic 25 yr
10	11,060	4,839	4,387	4,387
20	28,681	14,433	8,775	4,387
30	68,010	37,256	13,162	8,775
40	217,008	96,874	17,549	8,775
50	529,433	258,837	21,937	8,775

plot - 10 pile job (recycle)

Remaining Design Life	timber 3 yr	timber 5 yr	plastic 10 yr	plastic 25 yr
10	11,060	4,839	4,161	4,161
20	28,681	14,433	8,322	4,161
30	68,010	37,256	12,483	8,322
40	217,008	96,874	16,644	8,322
50	529,433	258,837	20,805	8,322

replacement year	P = C+M(1 (1+i	Total Cost (cum P)
	2,085	2,085
3	2,445	4,530
6	2,933	7,463
9	3,597	11,060
12	4,500	15,560
15	5,727	21,287
18	7,394	28,681
21	9,660	38,341
24	12,741	51,082
27	16,928	68,010
30	22,619	90,629
33	30,354	120,983
36	40,868	161,850
39	55,158	217,008
42	74,581	291,589
45	100,981	392,570
48	136,864	529,433

replaceme year	P = C+M(1 (1+i	Total Cost (cum P)
	2,085	2,085
5	2,753	4,839
10	3,868	8,706
15	5,727	14,433
20	8,826	23,260
25	13,996	37,256
30	22,619	59,875
35	36,999	96,874
40	60,982	157,856
45	100,981	258,837

Remaining Design Life	timber 3 yr ($)	timber 5 yr ($)	plastic no recyle 10 ($)	plastic no recyle 25 ($)	plastic recyle 10 ($)	plastic recyle 25 ($)
10	11,060	4,839	4,387	4,387	4,161	4,161
20	28,681	14,433	8,775	4,387	8,322	4,161
30	68,010	37,256	13,162	8,775	12,483	8,322
40	217,008	96,874	17,549	8,775	16,644	8,322
50	529,433	258,837	21,937	8,775	20,805	8,322

platic 25 yr. vs. timber 3 yr.

Remaining Design Life	cost savings per pile no recycle pw $	% savings	cost savings per pile recycle pw $	% savings
10	6,673	60.3%	6,899	62.4%
20	24,293	84.7%	24,520	85.5%
30	59,235	87.1%	59,688	87.8%
40	208,233	96.0%	208,686	96.2%
50	520,659	98.3%	521,112	98.4%

platic 25 yr vs. timber 5 yr.

Remaining Design Life	cost savings per pile no recycle pw $	% savings	cost savings per pile recycle pw $	% savings
10	451	9.3%	678	14.0%
20	10,046	69.6%	10,273	71.2%
30	28,481	76.4%	28,934	77.7%
40	88,099	90.9%	88,552	91.4%
50	250,062	96.6%	250,515	96.8%

timber 3 year life

facility remaining life	timber (3 yrs)	plastic-no recycle (10) yrs	plastic-no recycle (25) yrs	savings plastic no recycle 10 yrs	savings plastic no recycle 25 yrs
10	2,085	4,387	4,387	-2,302	-2,302
10	4,530	4,387	4,387	142	142
10	7,463	4,387	4,387	3,076	3,076
10	11,060	4,387	4,387	6,673	6,673
20	15,560	8,775	4,387	6,785	11,173
20	21,287	8,775	4,387	12,512	16,899
20	28,681	8,775	4,387	19,906	24,293
30	38,341	13,162	4,387	25,179	33,954
30	51,082	13,162	4,387	37,920	46,695
30	68,010	13,162	8,775	54,848	59,235
40	90,629	17,549	8,775	73,079	81,854
40	120,983	17,549	8,775	103,433	112,208
40	161,850	17,549	8,775	144,301	153,076
40	217,008	17,549	8,775	199,459	208,233
50	291,589	21,937	8,775	269,652	282,814
50	392,570	21,937	8,775	370,633	383,795
50	529,433	21,937	8,775	507,497	520,659

timber 5 yr life

timber (5 yrs)	plastic-recycle (10 yrs)	plastic-recycle (25 yrs)
2,085	4,161	4,161
4,839	4,161	4,161
8,706	8,322	4,161
14,433	8,322	4,161
23,260	12,483	4,161
37,256	12,483	8,322
59,875	16,644	8,322
96,874	16,644	8,322
157,856	20,805	8,322
258,837	20,805	8,322